Transaction Costs and the Collection of Information: Presale Measurement on Private Timber Sales

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Measurement efforts to reduce the uncertainty concerning the attributes of heterogeneous goods may simply redistribute wealth and result in social waste. Individuals bearing the cost of such distributional measurement have incentives to develop buying and selling practices that limit such measurement. We examine, both theoretically and empirically, the determinants of the level of distributional measurement efforts in a competitive auction framework. The empirical application, which uses a sample of private timber sales, provides strong support for the implications of the theoretical model of presale measurement.

Buyers of goods rarely know the exact characteristics of their purchases. Even if buyers are risk neutral, this uncertainty motivates them to expend effort to find the best buys. For produced goods, such measurement costs can be socially valuable as the more efficient producers are differentially rewarded and therefore expand production. In many situations, however, the characteristics of the alternatives available are not affected by buyers' measurement efforts. Used cars with slipping transmissions do not run better just because they are identified. In these cases, measurement by buyers with equal valuations simply redistributes

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wealth from sellers to buyers and results in social waste. We refer subsequently to such wealth-dissipating presale measurement as distributional measurement.

Waste implies the potential for someone to be made better off without harming another. The individual or individuals bearing the cost of inefficient distributional measurement are expected to develop buying and selling practices that limit such measurement. This was a major theme of Barzel's 1982 article on measurement costs in which he explains, for example, the provision of warranties, choices between lump sum and royalty payments, and such sales practices as block booking and bundling.

In recent years there has been a growing literature that uses the general theory of transaction costs to explain the determination of observed and efficient contract provisions. Work in this area includes Cheung (1969), Mulherin (1986), Joskow (1987), Crocker and Masten (1988), Allen and Lueck (1992 and 1995), and Lyon and Hackett (1993).[1] Measurement costs have played an important role in understanding certain aspects of contract choice in this literature. French and McCormick (1984), for example, provide an analysis of how presale measurement affects the equilibrium in a competitive auction framework, and the 1991 study of private timer sales by Leffler and Rucker demonstrates that reduction in inefficient information collection is useful in explaining the choice of pricing provisions in timber sales contracts. In both of these studies, the level of buyer measurement was treated as exogenous.[2] In this article we examine, both theoretically and empirically, the determinants of the level of distributional measurement. Our goal is to improve our understanding of how wealth is increased through the development of economic institutions and contractual structures that reduce the incentives to seek distributional information.

As in the earlier study by Leffler and Rucker, the empirical analysis in the present study employs data on private timber sales contracts.[3] There are at least three reasons why natural resource sales, including in situ oil, coal, gold, and other minerals, as well as standing timber, are particularly useful transactions for the study of measurement activities. First, these goods can be treated as products of nature whose characteristics and quantities are not altered as a result of the collection of buyer

1. Shelanski and Klein (1995) review the empirical transaction costs literature and provide an extensive list of citations.

2. Much of the research in the auction literature either ignores presale measurement costs or assumes such costs to be zero. This leads to a peculiar feature of many auction models—a competitive equilibrium that requires an infinite number of bidders.

3. The dataset used in the present study is not the same as that used in Leffler and Rucker (1991). Details on the collection of this new dataset are provided in Section 2 below and in Munn (1993).

information or the provision of seller information. Further, as inputs into the production of other goods that are sold in competitive markets, the ultimate market value of these resources likely is the same for all buyers. Hence, expenditures on information are mainly valuable because any differential between extraction cost and value can be captured by one rather than another individual.

Second, the relative uniqueness of each sale makes for substantial uncertainty as to the value, thereby motivating presale measurement efforts. Thus, prospective buyers of mineral or oil extraction rights conduct costly geological and seismic tests and potential buyers of standing timber conduct detailed cruises of sales tracts. Unlike the costs involved, for example, in searching for a used car, there is a reasonable chance with natural resource sales of objectively quantifying differences across tracts in the measurement costs involved.

Third, natural resources often are sold in competitive auction settings. This not only results in well-kept records concerning the details of the sale but also allows us to build upon the extensive economics literature describing the competitive equilibrium in such auctions.

In Section 1 we review the theoretical literature relevant to the determination of how privately optimal levels of buyer measurement expenditures in an auction are affected by the characteristics of the auctioned good. This literature provides us with the basic result that we extend to develop our empirical propositions. The basic result is that for an exogenously given number of bidders, individual buyers will increase their presale measurement efforts when there is an increase in the ex ante uncertainty concerning the value of the good being auctioned. We then develop this implication to consider the impact of endogenous changes in the number of bidders. We demonstrate that if the level of uncertainty increases and, as a result, the number of bidders also changes, we cannot predict that the level of individual measurement will necessarily increase. The total amount of measurement by all bidders, however, is unambiguously predicted to increase. Section 1 concludes with consideration of seller incentives to alter sales procedures and contract provisions as a consequence of changes in the total amount of buyers' presale measurement expenditures. In particular, we predict that the sellers, who ultimately pay the buyers' measurement costs through lower bid prices, will themselves engage in more presale measurement when the level of uncertainty is greater. In effect, the seller's measurement efforts and the resulting information act as a substitute for the duplicative measurement efforts of the buyers.

In Section 2 we test the predictions developed in Section 1 using a dataset that contains information from a sample of private timber sales in North Carolina. The dataset includes information on the buyers' or the sellers' measurement efforts on individual timber tracts and on a variety of other variables, including physical characteristics and contract provisions. We use a subset of the variables as proxies for different dimensions of the underlying uncertainty concerning the value of the tracts. Our empirical results strongly support the predictions of the theory—total buyer measurement increases when uncertainty increases, and sellers increase their provision of information to buyers when the expected level of aggregate buyer measurement increases. Finally, in Section 3 we discuss additional implications of our analysis for the optimal choice of contracts as well as promising extensions.

1. Presale Measurement in Competitive Auctions

In 1977, Robert Wilson published an article that presented a theoretical model of auctions incorporating the phenomenon of the winner's curse.[4] This curse arises in common value auctions, where the true value of the auctioned good is the same for all potential buyers, but is unknown at the time of purchase. In Wilson's model, the bidders acquire an informational sample that they use to develop an estimate of the value of the good. The problem arises because none of the bidders knows the information samples received by other bidders. Thus, the bidder who receives the best information sample does not know that he has almost certainly received biased information. If he submits a bid assuming his sample is unbiased, he will (on average) lose money. Wilson demonstrates that this "winner's curse" problem is avoided if each bidder adjusts his estimate of the value of the good based on the assumption that he has received the highest information sample. Although all but the winning bidder are wrong in making this assumption, all the bidders increase their ex ante payoffs by assuming they will win.

In Wilson's analysis, the bidders' information is acquired costlessly. Of course, if the amount of information could be increased costlessly, all bidders would simply take an infinite number of samples and all would become fully informed. Milgrom (1981) moved the theory in the direction of empirical relevance by examining the implications of costly information acquisition. Milgrom's analysis, however, did not allow for a full competitive equilibrium because he fixed the number of bidders. This implies that the winner of the auction could have positive expected profits. In addition, the level of information was a dichotomous choice —take a single sample or not.

In a pair of articles, Milgrom and Weber (1982a, b) extended the analysis to examine issues related to the collection of variable and costly information by buyers. They also addressed the issue of whether sellers will reveal their private information to buyers and came to the important insight that a seller may benefit from truthful ex ante revelation of his information to buyers.

4. See Thaler (1992) for a discussion of the history of the winner's curse in the context of auctions for oil drilling rights. French and McCormick (1984) present an intuitive discussion of Wilson's model.

Matthews (1984) extended this theme by developing a model with endogenously determined amounts of costly bidder information in a setting with alternative (exogenously determined) numbers of bidders. He confirmed Milgrom and Weber's findings that sellers bear the costs of buyer measurement and also suggested that "production of enough public information will decrease the incentives for bidders to acquire private information,... and increase the seller's expected profit."[5]

While Matthews' analysis suggests that zero buyer profit can result with the correct number of bidders, his model does not have an endogenously determined number of bidders that leads to such an equilibrium. Hausch and Li (1993) provide this extension in a model in which both the bidder entry decision and the information acquisition decision are endogenous. They find that in equilibrium the expected difference between the value of the auctioned good and the winning bid will equal the sum of the individually optimal buyer expenditures on information collection. It follows that the bidders will have zero expected profits from participation in the auction, and the seller will indirectly pay for the information collected by the bidders.

Several of these articles arrive at the same conclusions as did Barzel in his 1982 analysis of measurement cost—because the seller ultimately bears the costs of the buyers' measurement efforts, the seller has an incentive to take actions to reduce the buyers' incentives to engage in presale measurement. Indeed, Hausch and Li show that if the seller can limit the acquisition of information (without impacting the buyers' expectations of value), the seller's profits can increase. None of these articles, however, consider the impact on endogenously determined buyer information costs from changes in the structure of the auction that may alter the buyers' incentive to measure.

Two of the present authors, Leffler and Rucker, analyzed the impact on buyer measurement costs from seller's choice of a lump sum versus a per unit payment provision in an auction. The hypothesis was developed and tested that the choice between these payment provisions will be determined in part by the buyers' incentives to engage in presale measurement and information collection. Specifically, it was found that on tracts with greater value uncertainty (where buyers have greater incentive for presale measurement), sellers were more likely to specify per unit payment provisions, which lower the buyers' incentives to measure. The same theme was pursued by Gaier (1995) in a theoretical analysis of bidder information collection in first price (lump sum) versus royalty rate (per unit) mineral rights auctions. His model also yielded

5. As Matthews notes, similar results were part of the auction literature concerning offshore oil leases. That literature, however, was based on numerical simulations that did not provide any general comparative statics results. Further, the amount of information was not a choice variable.

the prediction that there will be more information collected by buyers in the more risky lump sum auctions.

It is thus well established in the literature that the value to the seller of an auctioned good can be reduced by buyers' presale collection of information. In addition, it is recognized that the choice of payment provisions can affect the value of the good to the seller by altering the buyers' measurement incentives. The literature has not, however, directed much attention to the issue of how the characteristics of the auctioned good itself might affect the collection of presale information by buyers. This is one theme of a recent article by Persico (1997), who confirms the intuitive proposition that the amount of information collection activity by individual auction participants will increase with an increase in the ex ante uncertainty of the value of the auctioned good. Of importance for our empirical analysis, Persico also demonstrates that holding constant the variance of the value of the auctioned good, a change in the mean value does not impact the incentive to collect presale information.[6]

In most actual auction situations—including our empirical analysis of timber sales—there is free entry with the number of bidders determined endogenously. Persico's theoretical results, however, are derived with the number of bidders held constant. Changes in the level of uncertainty likely will affect the number of bidders, which in turn will alter the measurement incentives of each bidder. Thus, we cannot directly apply Persico's result to actual auction settings.

The effects of a change in uncertainty on presale measurement with an endogenous number of bidders can be shown using Figure 1, which displays the relationship between the number of bidders N, the expected level of the winning bid B, and the true value of the auctioned item v (which is the realization of the random variable V).[7] The expected winning bid B is a function of the exogenously given level of

6. To understand the intuition underlying this prediction in the context of our empirical analysis (timber sales), consider the following. Assume a tract whose expected value is \$1000, and whose actual value may be either \$900 or \$1100 (that is, the probability density function of the tract's value is binomial). The potential gains from measurement arise from being able to identify (or increase the probability of identifying) the tract as either a high-value tract or a low-value tract. Contrast this tract with another tract whose expected value is \$100,000 and whose actual value may be either \$99,900 or \$100,100. That is, the value density function of the second tract represents a variance preserving shift of the density function of the first tract. The incentives of risk-neutral buyers to measure, which arise from the possible differences in the tract value, are the same on the two tracts. Essentially, neither the marginal benefits nor the marginal costs of measuring have changed.

7. This framework is adapted from the graphical analysis first offered by Johnson (1979) and later extended by French and McCormick. See French and McCormick for an intuitive explanation for why the expected bid approaches the true value of the tract in this analysis as the number of bidders increases.

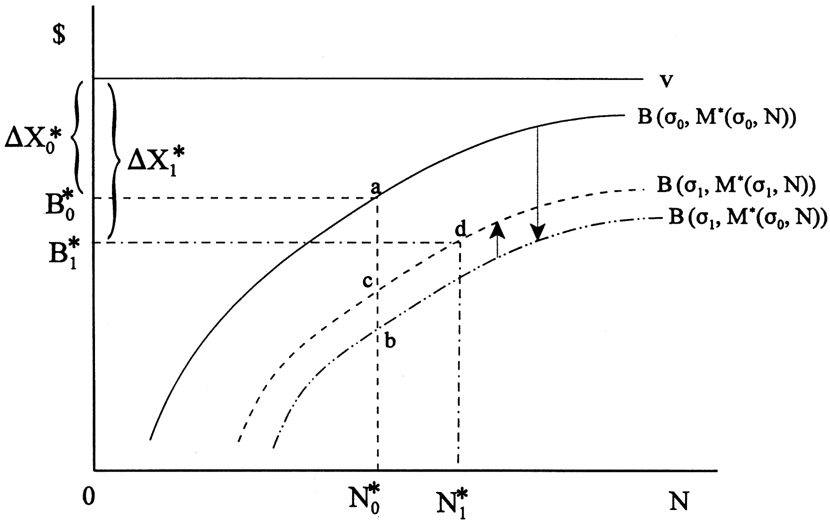

Figure 1. Impacts of an increase in intrinsic uncertainty.

ex ante uncertainty σ_0,[8] the endogenous level of individual buyer presale measurement M^*, and the endogenous number of bidders. With entry and competition among buyers, the initial equilibrium bid B_0^*, and number of bidders N_0^*, in Figure 1 satisfy the zero-profit condition that the expected gains from entry, $(v - B)/N = \Delta X/N$, are equal to the costs of entry, which in the present context are simply the cost of undertaking presale measurement, M. Note that the equilibrium condition $\Delta X/N = M$ can be rewritten as $\Delta X = M \cdot N$, which indicates that the expected prize to the winning bidder is equal to the aggregate costs of buyer measurement.

Further, the expected prize to the winning bidder, $v - B = \Delta X$, falls as the number of bidders increases. Because it is the prospect of this prize that motivates presale measurement by prospective buyers, along the expected bid curves in Figure 1, the level of individual measurement, $M^*(\sigma_i, N)$, decreases with the number of bidders.[9]

Consider now the effect of an increase in the level of uncertainty. The initial impact is a shift down in the bid curve [from $B(\sigma_0, M^*(\sigma_0, N)$

8. By ex ante uncertainty, we refer to the intrinsic uncertainty concerning the value of a good when no information on its characteristics is available. In our application to timber sales, the ex ante uncertainty would be the level of uncertainty prior to a formal timber cruise by either the seller (or a timber consultant acting as an agent for the seller) or prospective buyers. This construct corresponds to the initial level of uncertainty in theoretical models of behavior under uncertainty.

9. Note that this aspect of our graphical framework differs from French and McCormick, who held constant the level of individual measurement.

to $B(\sigma_1, M^*(\sigma_0, N)$ in Figure 1].[10] Holding constant the number of bidders and the level of individual measurement, the resulting increase in the expected prize to the winning bidder corresponds to the movement from point a to b in Figure 1. As Persico demonstrated, however, the increased prize will induce increased individual measurement. This increased measurement reduces the (postmeasurement) uncertainty concerning the value of the tract, thereby causing the bid curve to shift back up. This shift is represented in Figure 1 by the movement from the bid curve $B(\sigma_1, M^*(\sigma_0, N)$ to the curve $B(\sigma_1, M^*(\sigma_1, N)$. The associated reduction in ΔX for the initial equilibrium number of bidders N_0^* corresponds to the movement from point b to point c. In addition, the increased prize may motivate entry, which would result in a further reduction in the expected prize, ΔX, as indicated by the movement from point c to d.[11] If there is entry then (relative to the initial movement from a to b) both effects—increased individual measurement and increased numbers of bidders—will reduce the prize to the winning bidder, ΔX. Even in this case, of course, the factor that caused both the increase in the number of bidders and in each bidder's individual measurement efforts was the increase in ΔX. Thus, the new equilibrium value of ΔX must be greater than the initial value (in Figure 1, the increase is from ΔX_0^* to ΔX_1^*). Therefore, because aggregate measurement expenditures must in equilibrium equal the expected prize, ΔX^*, aggregate measurement will increase when the level of uncertainty increases.

As has been discussed, because the seller will ultimately bear the cost of the bidders' measurement, the seller clearly has incentives to adopt sales provisions and procedures that reduce these costs, thereby increasing the net social value of the auctioned good. A seller can take a number of actions that will affect buyers' incentives to engage in wealth-dissipating presale measurement. Such actions include restrictions on the buyers' ability to collect presale information by, for example, limiting the time that the good is available for inspection or by altering the costs of the information collection by, for example, holding the auction during stormy seasons.

The seller also can take actions that reduce the uncertainty faced by the buyers. For example, the seller can specify less risky payment provisions like per unit (for timber) or royalty (for mineral rights) payments rather than requiring lump sum payment. Alternatively, the

10. Intuitively, this shift occurs because, for a given number of bidders, an increase in the level of uncertainty leads to an increase in the difference between the highest and second-highest information samples (and all other ordered information samples). It is these differences that determine the level of the bid and the size of ΔX for any given number of bidders in this auction model.

11. The direction of the change in the number of bidders is ambiguous because the individual costs of measurement have also increased. If the number of bidders falls there is a movement to the left from N_0^*, which considered alone increases the prize to the winning bidder.

uncertainty faced by the buyer can be reduced if the seller undertakes presale measurement and makes the results available to all potential buyers. The incentives for buyer presale measurement thus imply that sellers will engage in greater presale measurement when auctioning goods with greater uncertainty.

2. Empirical Analysis of Presale Measurement

Our empirical analysis focuses on presale measurement in timber auctions. To provide background for understanding the role of presale measurement in the timber industry, we begin this section with a brief discussion of timber cruising. We then discuss the testable implications from the previous section in the context of timber sales. Finally, we describe the data collection procedures, define the variables used in our empirical analysis, and present the results of our empirical tests of the theory developed in Section 1.

2.1 Background on Timber Sales

Private timber often is sold to be converted to more highly valued lumber by auction of the rights to cut the timber. The purchaser of the timber cutting rights then has a relatively short period in which to cut and remove the logs.[12] The purchaser does not, of course, know with certainty either the volume or the per unit value of the timber on the tract. Prior to the auction, however, the seller usually provides an estimate of the type, quality, and volume of timber. In addition, the seller allows prospective buyers to inspect, or cruise, the tract.

The methods for presale evaluation of timber tracts are well developed.[13] Foresters cruise a timber tract to determine the quantity and quality of timber present. A standard method is a fixed-radius plot cruise in which circular plots of a predetermined area, typically one-tenth of an acre in the region where our data were collected, are measured throughout the tract. In each plot, estimates of diameter at breast height (dbh) and total merchantable height for every tree are recorded on tally sheets by species and commodity class (pulpwood, chip-and-saw, sawtimber). Typically, cruisers adjust the number of plots to achieve the desired sampling level.[14]

As part of the cruise, the forester also notes terrain features and other information that may affect logging costs. Following the cruise,

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12. Private timber sale contracts are usually 24 months or less in duration. By defining our "period" as the typical contract length, we abstract from the temporal aspects of the cutting decision.

13. These methods are described in, for example, the discussion of cruising in Wenger (1984).

14. Alternatively, the volume of timber on a tract may be measured using a prism cruise, which typically is quicker than a fixed-radius plot cruise, but subject to greater variance. See, for example, Wenger (1984) for further details on the mechanics of this method. In Leffler, Rucker, and Munn (1996), we provide an analysis of the determinants of the choice of cruise method.

published conversion tables are used to convert the numbers of trees tallied by dbh, height, species, and commodity class into an estimate of total volume.

2.2 Testable Implications

Our basic and intuitive prediction is that the total amount of buyer presale distributional measurement will increase with increases in the bidders' uncertainty concerning the value of the auctioned timber-harvesting rights. Changes in the level of uncertainty might result from various sources.

One obvious source of uncertainty concerning the value of a timber tract is the physical characteristics of the tract. For example, an increase in tract heterogeneity (due to a change in the species composition of the tract from types of timber with easy-to-evaluate attributes, to types of timber with more difficult-to-evaluate attributes) or in the volume of timber on a tract will increase the level of uncertainty and the aggregate amount of buyer presale measurement. Forests in the North Carolina area from which we obtain our data contain hardwoods such as maple or oak, pine sawtimber, "chip-and-saw," and pulpwood timber. Maple, oak, or pine sawtimber can yield sawmill products with a substantial variance in value depending upon the particular characteristics of the individual trees.[15] In contrast, chip-and-saw and pulpwood timber yield primarily low-value products such as pulp stock and firewood with little variance in value by tree characteristic. Based on the discussion in Section 1, we therefore predict that aggregate buyer presale measurement will be greater, ceteris paribus, on timber tracts with higher proportions of the highly variable hardwood and pine sawtimber. Buyers' incentives to expend resources to accomplish wealth transfers in timber purchases also are affected by the expected volume contained in the tract. Holding the tract's expected composition constant, a larger volume implies a larger variance and therefore a greater incentive to engage in distributional measurement.[16]

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15. This variation in value is typified by the following examples of recent Appalachian hardwood market prices: The average price of first- and second-grade red oak is \$1150/mbf as compared with \$605/mbf for #2 common; first- and second-grade hard maple is \$1645/mbf as compared with \$605/mbf for #2 common. See *Weekly Hardwood Review* (April 24, 1998).

16. To see that an increase in volume increases variance, consider a tract with one tree whose perceived size and quality (according to the seller-provided information) are such that the expected value of the tract is \$110, and that prospective buyers' perceptions are that the actual value of the tract is either \$100 or \$120, both with probability of .5. Now, suppose the number of trees on the tract doubles to two. Assuming that the expectations concerning the second tree are identical to the first (i.e., holding composition constant), the tract now has an expected value of \$220 with potential realized values of \$200 with probability .25, \$220 with probability .50, and \$240 with probability .25. The variance of the tract thus increases from 100 to 200 with the increase in volume. We discuss below the effects of an increase in value that can accompany an increase in volume or that can occur for other reasons.

Our discussion of measurement in Section 1 was in terms of the dollar amount of measurement expenses incurred by buyers as a group. In fact, the information we have been able to obtain on buyer and seller measurement concerns the physical amount of cruising (e.g., the number of trees counted) and not of the expenditures or cost incurred in cruising. Of course, as long as the wages paid to timber cruisers is relatively constant there will be a direct and linear relationship between the expenditures on measurement and the number of trees measured. Because our data concerns a specific geographical area over a relatively short time interval, there should be no significant variation in wages. From the literature on timber cruising, however, we conclude that the marginal costs of measuring trees will fall as the density of timber on a tract increases.[17] Therefore, we predict that the number of trees counted, which is our primary meter of presale measurement, should be greater on tracts with greater volume per acre.

We also include a variable to control for the size of buyers. Under our model, however, offsetting effects preclude obtaining a prediction for this variable. Larger, more experienced buyers may be better able to evaluate the information from a given percentage cruise, and will therefore conduct less-intensive cruises. Larger buyers, however, may also be more experienced at presale measurement and may cruise more tracts at a lower average cost. These lower costs of measurement will lead to an offsetting increase in cruising effort. Finally, we include VOLUMESQ, the total volume squared, to allow flexibility in the estimated impacts of changes in volume on measurement.

2.3 Data Collection and Variable Definitions

To test the preceding predictions, we use data on private timber-harvesting contracts collected from timber buyers, sellers, and forestry consultants throughout North Carolina. Collection of these data from buyers was initiated by mailing to all timber buyers listed in *Buyers of Forest Products in North Carolina* (1989) a brief description of the study and a request to indicate whether they would be willing to participate. A similar approach was used to contact timber consultants (who act as sellers' agents) operating in North Carolina. Those who agreed to participate were mailed sale questionnaires that asked detailed ques-

17. This discussion implicitly defines measurement units in terms of the number of trees evaluated. In our discussion of the determinants of presale measurement in the previous section, however, we used time units to indicate the quantity of measurement effort. Using that convention, a denser timber tract increases the marginal benefit of measurement. Regardless of the semantic difference between time spent and dollars spent on measurement, the empirical implication (an increase in measurement) is unchanged. Further, such a shift in the marginal benefits of measurement increases the optimal "amount" of measurement, in terms of both the time spent measuring and the expenditures on measurement.

tions about individual sales.[18] Through this process, which extended over more than a year's time, we obtained information on empirical proxies for the variables suggested by the preceding discussion for 150 usable timber-harvesting contracts from recent years. Of these, information on 104 sales was provided by winning bidders and information on 46 sales was from timber consultants and sellers. Thus, our analysis of the amount of buyer measurement comes from the information provided by the 104 winning bidders, while our analysis of seller measurement is from the remaining 46 sales.

Each participating buyer or seller provided information on his own cruising activities on individual tracts.[19] Each buyer typically provided information on several tracts. The information provided on each tract included the extent of his cruise, his cruise-based (ex ante) estimates of the volumes of different species and commodity classes of standing timber on the tract, the number of bidders for the tract, the type of payment provisions used, the nature of the sales procedure, assessments of the accessibility of the tract and of the overall quality of the timber on the tract, and the duration of the contract. Each seller/consultant that participated in our survey indicated the extent of the cruise he conducted on several individual tracts for the purpose of providing public information to prospective buyers, as well as the same information on tract characteristics and other factors as was provided by buyers. Consistent with the discussion in Section 1, all of the sales used for the empirical analysis below are lump sum auction sales. A brief description of the empirical proxies for our dependent and independent variables follows. Table 1 displays the variable names (with brief descriptions), sample statistics, and predicted effects for these proxies. Table 2 presents a correlation matrix.

2.4 Empirical Proxies

The first dependent variable used in the empirical analysis reported below is a measure of the total volume of timber cruised by all buyers for each sale in our sample. The industry standard for indicating the degree of cruising effort on fixed-radius plot cruises is the percentage of the tract that was cruised. For purposes of our empirical analysis, therefore, the level of measurement is in terms of the volume of timber measured. From the information we collected on cruise percentages and on the respondents' estimates of the volumes of various species and commodity classes of timber on each tract, we construct an estimate of

18. For a detailed discussion of the procedures used to collect these data, see Munn (1993). Because many timber sellers are small, nonindustrial, private landowners it was not cost effective to contact more than a small number of them.

19. Copies of the survey instrument are available on request from the authors. Note that each survey response provides us with information on either the buyer's cruising activities on individual tracts or the seller's activities, but not both.

Table 1. Variable Definitions, Predicted Effects, and Sample Statistics (104 Lump Sum Auction Observations from Buyers)

	Proxy	Definition	Predicted Sign	Mean	Minimum	Maximum	Standard Deviation
Dependent Variables							
Amount presale cruise	BUYER VOLUME CRUISED	Estimated total volume cruised by all prospective buyers of the tract		584.86	0	4470.59	698.25
Amount presale cruise	BUYER PLOTS CRUISED	Estimated total number of plots cruised by all prospective buyers of the tract		580.63	0	5280.00	708.55
Independent Variables							
Ex ante uncertainty	% SAWTIMBER	Percentage of sawtimber on the tract	Positive	70.15	7.61	100.00	22.85
Ex ante uncertainty	VOLUME	Volume all species (mbf) on the tract	Positive	688.05	58.00	4380.98	710.10
Ex ante uncertainty	VOLUMESQ	VOLUME squared	No prediction	972,809.00	3364.00	19.2×10^6	2.47×10^6
Cruising cost	DENSITY	Tract density (VOLUME / acre)	Positive	11.03	1.47	32.58	5.21
Buyer size	BUYER SIZE	0 / 1 / 2 dummy for small (0), medium (1), or large (2) buyers	No prediction	1.35	0	2.00	0.68
Tract value	VALUE	Estimated value of tract (1990 $)	Zero effect	85,665.00	9061.97	542,825.00	85,287.00
Ex ante uncertainty	FUTURES PRICE	Expected future price of lumber ($ / mbf) at time of sale	Positive	173.09	155.74	188.03	9.58

Table 2. Correlation Matrix

	BUYER VOLUME CRUISED	BUYER PLOTS CRUISED	% SAWTIMBER	VOLUME	VOLUMESQ	DENSITY	BUYER SIZE	VALUE	FUTURES PRICE
BUYER VOLUME CRUISED	1.000								
BUYERS PLOTS CRUISED	0.785	1.000							
% SAWTIMBER	0.130	0.098	1.000						
VOLUME	0.244	0.142	−0.255	1.000					
VOLUMESQ	0.193	0.114	−0.144	0.921	1.000				
DENSITY	0.298	−0.152	0.068	0.137	0.093	1.000			
BUYER SIZE	−0.061	−0.123	−0.120	0.140	−0.023	0.056	1.000		
VALUE	0.268	0.157	−0.171	0.961	0.874	0.132	0.134	1.000	
FUTURES PRICE	−0.045	0.067	−0.010	0.003	−0.046	−0.167	0.274	0.007	1.000

Pearson correlation coefficients, $N = 104$.

the measurement efforts of the contacted buyer as the product of his reported cruise percentage and volume.[20] As indicated in Section 1, the relevant quantity from the perspective of efficient contracting is the total amount of buyer measurement. We construct the first dependent variable for our analysis, BUYER VOLUME CRUISED$_i$, as the product of the estimated level of individual measurement just described and the number of bidders for tract *i*.[21]

In part to demonstrate the robustness of our empirical results, we also construct a second dependent variable. This variable, BUYER PLOTS CRUISED$_i$, is the total number of plots cruised by prospective buyers of tract *i*. To construct this variable, we first estimate the number of plots cruised on a tract by the contacted buyer. We obtain this estimate using information the buyer provided on his percentage cruise, the number of acres of the tract, and the fact that cruisers in the region cruise plots of 0.10 acres in size. The total number of plots cruised is estimated as the number cruised by the contacted buyer multiplied by the number of competing buyers for the tract. With one exception (discussed below) the predictions for the two dependent variables are the same.

2.5 Independent Variables

Our empirical proxies are consistent with the earlier discussion of our testable implications. Ex ante uncertainty is measured with the percentage of sawtimber (% SAWTIMBER) and the estimated volume of timber (VOLUME) on the tract. Both of these variables are predicted to positively affect cruising efforts. An increase in tract DENSITY reduces cruising costs; thus we predict that more timber will be cruised as density increases. This implies a positive coefficient for DENSITY in the regressions with BUYER VOLUME CRUISED. An increase in

20. The industry practice is to estimate amounts of different types of timber using different volume metrics (or log tallies). As examples, the volume of pine sawtimber is typically measured in thousand board feet (mbf) Scribner log tally, the volume of hardwood sawtimber is often measured in mbf Doyle, and the amount of pulpwood is often measured in cords. We obtain our estimate of the total volume of timber on each tract by using standard industry factors to convert all volumes to mbf Scribner log tally. See *Timber Mart South*, Avery and Burkhart (1983: 50–53), and Munn (1993: 18) for the conversion factors used and discussions of such conversions in the timber industry. Alternative empirical specifications (which require making fewer of the conversions described above), using the individual volumes of the separate species and commodity classes, yield results that are qualitatively the same as those shown in Table 3.

21. As indicated above, we obtained information on the number of competing buyers for each sale in our sample from the buyers and seller/consultants who participated in our survey. This information is, of course, a part of the records kept by consultants. Moreover, buyers typically record the bids of competing bidders as they are opened at the auction. For the sales in our empirical analysis, we use this bid information to tally the number of bidders.

density, however, increases the cost of cruising a given plot (because the tract contains more trees/timber), which suggests that the number of plots cruised will decrease as density increases. Thus, in the regression reported below with BUYER PLOTS CRUISED as the dependent variable, we expect the estimated coefficient on DENSITY to be negative. BUYER SIZE is an integer variable, with 0, 1, or 2 indicating small, medium, or large buyers. We have no prediction concerning the sign of the estimated coefficient for either this variable or for VOLUMESQ. The other independent variables listed in Table 2, VALUE and FUTURES PRICE, are discussed below.

2.6 Empirical Results

Regression results are reported in Table 3. Regressions 1–3 present results for the determinants of cruising intensity using the first dependent variable described above, BUYER VOLUME CRUISED. Because three of the 104 sales in the sample had zero volume cruised, our estimates are from TOBIT models. Regression 1 provides the most parsimonious test of our prediction that an increase in the level of uncertainty increases total buyer measurement. The only two variables included in this regression are two measures of intrinsic uncertainty, % SAWTIMBER and VOLUME. The estimated coefficients for both of these variables are positive, as predicted, and highly statistically significant.

Regression 2 includes the other variables discussed above. As predicted, the estimated coefficient on DENSITY is positive and statistically significant at an α level of 0.05. BUYERSIZE is estimated to have a negative and marginally significant effect on the volume of timber cruised. The estimated coefficient on VOLUMESQ is negative and significant, implying that measurement increases at a decreasing rate with volume. The estimated coefficients on % SAWTIMBER and VOLUME are not substantively affected by the addition of these other variables.

A common belief in the timber industry seems to be that higher-valued tracts are cruised more intensively. A widely used forestry text, in its discussion of timber cruising, states that, "Other things being equal, the intensity of sampling tends to increase ... as the value of the timber increases" (Avery and Burkhart, 1983: 185). The economic models of presale measurement discussed in the previous section suggest that any effect of value on the buyers' incentive to measure must arise because the change in value also affects the level of uncertainty. Holding species composition and volume constant, as we do in our analysis, the value of tracts of timber can vary for two reasons—the price of logs can vary or the costs of harvesting can vary. An increase in the price of logs (holding volume constant) is predicted to have an effect on buyer measurement that is identical to the effect of an increase in volume (holding log prices constant). That is, the variance in value is predicted

Table 3. Estimates of the Determinants of Cruising Intensity

		Regression[a]					
		1	2	3	4	5	6
Dependent Variable		BUYER VOLUME CRUISED	BUYER VOLUME CRUISED	BUYER VOLUME CRUISED	BUYER VOLUME CRUISED	BUYER PLOTS CRUISED	SELLER VOLUME CRUISED
Explanatory Variable	Predicted Coefficient						
INTERCEPT		−102.23 (0.681)	−415.79 (0.168)	−871.90 (0.477)	−727.59 (0.556)	−672.80 (0.607)	−22.53 (0.720)
% SAWTIMBER	+	6.645 (0.014)	6.749 (0.012)	6.221 (0.024)	6.565 (0.015)	6.542 (0.020)	—
VOLUME	+	0.304 (0.001)	0.718 (0.003)	0.532 (0.116)	0.783 (0.002)	0.732 (0.006)	—
VOLUMESQ	?	—	−1.32E-4 (0.070)	−1.23E-4 (0.098)	−1.48E-4 (0.047)	−1.47E-4 (0.063)	—
DENSITY	+[b]	—	33.690 (0.003)	35.199 (0.003)	32.906 (0.005)	−23.832 (0.038)	—
BUYER SIZE	?	—	−165.041 (0.104)	−171.923 (0.102)	−156.740 (0.140)	−213.877 (0.058)	—
VALUE	0	—	—	0.0013 (0.612)	—	—	—
ACCESS CONDITIONS	0	—	—	—	14.188 (0.817)	−44.773 (0.491)	

Continued

Table 3. *Continued*

		Regression[a]					
		1	2	3	4	5	6
Dependent Variable		BUYER VOLUME CRUISED	BUYER VOLUME CRUISED	BUYER VOLUME CRUISED	BUYER VOLUME CRUISED	BUYER PLOTS CRUISED	SELLER VOLUME CRUISED
Explanatory Variable	Predicted Coefficient						
DISTANCE TO MILL	0	—	—	—	−3.200 (0.287)	−1.930 (0.544)	
FUTURES PRICE	+	—	—	2.835 (0.342)	2.231 (0.375)	6.722 (0.182)	—
PREDICTED BUYER MEASUREMENT	+	—	—	—		—	0.530 (0.0001)
Estimation Method		TOBIT	TOBIT	TOBIT	TOBIT	TOBIT	OLS
Number of Observations		104	104	104	104	104	46
Log Likelihood (TOBIT) / R^2(OLS)		−804	−798	−798	−797	−804	0.343

[a]Numbers in parentheses are *p*-values, which indicate the minimum level of test significance for which the hypothesis that the coefficient is zero is rejected. For the variables other than INTERCEPT, VOLUMESQ, BUYER SIZE, VALUE, ACCESS CONDITIONS, and DISTANCE TO MILL, the *p*-values are for one-tailed tests.
[b]For Regression 5, the predicted sign on DENSITY is negative.

to increase, and as a result, buyer presale measurement is predicted to increase. If, however, the costs of harvesting timber tracts vary, for example, because of terrain or distance from mills, the variance of tract value will be unaffected and no impact on presale measurement is expected.[22]

We test for the impacts of changes in value on buyer presale measurement by including two additional variables in Regression 3. VALUE_i is the estimated value of the timber on tract *i*.[23] FUTURE PRICE_i is the price of lumber futures contracts at the time the tract was sold.[24] In our regression specification, FUTURES PRICE is a proxy for changes in expected log prices due to changing market conditions. Thus, we interpret the estimated coefficient on VALUE as indicating the effect of differences in harvest or transportation costs. The prediction discussed above, that holding prices constant, such cost-based changes in VALUE will have no impact on buyer measurement, is confirmed by the results in Regression 3.

The insignificant coefficient on FUTURES PRICE, however, suggests that our data do not support the prediction that an increase in price increases buyer measurement. This result may be due to the limited variation in futures prices during the span of our data.[25] The addition of these two variables has little substantive impact on the other variables in the regression, although the significance of the volume and volume squared variables is reduced. This reduction in statistical significance is to be expected given the high degree of correlation (0.96) between VOLUME and VALUE in our dataset. Although multicollinearity does not cause bias in either the estimated coefficients or their standard errors (Greene, 1997: 423; Kennedy, 1998: 184), the extreme correlation between VOLUME and VALUE is potentially problematic.

22. A change in harvesting costs causes a mean preserving shift in the distribution of value.

23. The principle underlying this measure of value comes from standard auction theory, which suggests that on average the winning bid approaches the true value of the tract as the number of bidders becomes large. Accordingly, we estimated a bid price equation that included the natural logarithm of the number of bidders as one of the explanatory variables. Other explanatory variables included the volumes of various species and classes of timber on the tract, the duration of the contract, access conditions to the tract, distance to mill, and dichotomous variables to distinguish salvage sales and sales with high-quality timber. We then estimated each tract's "true" value as the predicted value from this regression using the estimated coefficients, the tract's actual characteristics, and a "large" number of bidders (we obtained virtually identical results with both 10 and 20 bidders—the average number of bidders on the sales in our sample is 4.7 and the maximum is 11).

24. More specifically, the value of this variable for a given tract is the simple average of the prices of the furthest-out futures contract traded on three (randomly chosen) days from the middle of the quarter in which the tract was sold.

25. The standard deviation of FUTURES PRICE is about 5% of its mean. In contrast, the standard deviation of VALUE is about equal to the mean.

Accordingly, we estimate our empirical model using two alternative variables as proxies for VALUE. These variables are ACCESS CONDITIONS, a qualitative ranking reported by survey respondents indicating how accessible the tract is for logging purposes, and DISTANCE TO MILL, as reported by the survey respondents for each tract. Although these two variables do not indicate a tract's value as accurately as our VALUE variable, they are both correlated with a tract's value, they are good indicators of harvest and transportation costs, and neither of them is significantly correlated with our measures of the variance in tract value.

Regression 4 displays the results of a specification that replaces VALUE with ACCESS CONDITIONS and DISTANCE TO MILL. As predicted by our measurement model, the coefficients on these two variables are not significantly different from zero. Further, the other coefficient estimates are not affected. In particular, the estimated coefficients on % SAWTIMBER and VOLUME remain highly significant.[26]

Regression 5 reports the results from a specification with the second dependent variable, BUYER PLOTS CRUISED. The predictions for this specification are the same as for the preceding specifications, with the exception discussed above that the coefficient on DENSITY is predicted to be negative. As can be seen from the results presented in Table 3, all of our predictions, including the negative sign on DENSITY, are confirmed with the second dependent variable.

The models of distributional measurement discussed in Section 1 demonstrate that sellers bear the costs of buyer measurement. As a result, sellers may benefit from finding ways to reduce buyers' incentives to measure. One means by which a seller can accomplish this is to undertake his own presale measurement and provide the resulting information to prospective buyers. In fact, sellers of timber tracts typically conduct their own cruises (or hire third parties to conduct such cruises) and provide information to buyers. We thus predict that an increase in expected total buyer measurement will induce sellers to undertake more presale measurement.

To test this prediction, we use information from a sample of 46 lump sum auction sales that we obtained from sellers. For these sales, we were provided information on the level of the sellers' cruises as well as

26. An additional comment concerns the industry practice of assessing cruising intensity on the basis of the *percentage* cruise. It might be argued that the quote in the text refers to predicted changes in this measure of cruise intensity rather than in the volume of timber cruised. Results similar to those reported in the text are obtained from a regression specification with the percentage cruise as the dependent variable—in particular, the estimated coefficients on the variables we include as proxies for a tract's value do not have a positive impact on the percentage cruise.

on the volume, composition, and other attributes of the tract. To test the prediction above, we construct an estimate of the predicted level of buyer measurement using the estimated coefficients from Regression 2 and the corresponding tract attributes for the 46 sales in the seller-provided sample. The results of the regression of the level of seller measurement on the predicted level of buyer measurement are shown as Regression 6 in Table 3.[27] The positive and highly significant coefficient on the predicted buyer measurement variable provides strong support for our prediction.[28]

3. Concluding Remarks

The regression results in Table 3 provide strong support for the economic theory of presale measurement. Cruising effort increases with the variance of the tract value (positive signs on % SAWTIMBER and VOLUME). In addition, buyer measurement increases with a reduction in the costs of cruising (positive sign on DENSITY). Further, sellers respond to an increase in the expected total amount of buyer measurement by increasing their measurement efforts.

The theory and results of this article imply that an understanding of the efficient and viable contracts in an economy requires an understanding of presale measurement. Our findings demonstrate that buyer distributional presale measurement can be significantly affected by the terms and conditions of the sale that are controlled by the seller. For example, our finding that larger timber sales volumes increase presale measurement less than proportionately implies that a single large sale will reduce the dissipation of the seller's rent as compared to two or more smaller sales. Similarly, we would predict that the use of a per unit rather than a lump sum sale would lower buyer uncertainty and thereby reduce buyers' incentive to engage in costly inspections prior to the sale.[29] Use of a per unit sale may, therefore, lead to an increase in the seller's net gains from the sale.[30]

The theory we have offered to explain buyers' presale measurement incentives also can be extended to provide other implications for the

27. Because none of the 46 observations in this sample had zero seller measurement, we estimate this specification with OLS.

28. It might be expected that the level of seller measurement will be affected by the costs of cruising a tract as well as by the expected level of buyer measurement. When we included DENSITY as a proxy for the level of measurement cost, however, it was not significant.

29. We test this prediction, although our dataset includes only three per unit auction sales. Despite the small number of per unit sales, we found substantially lower cruising effort on per unit (as compared to lump sum) sales. The estimated coefficients on a dichotomous PER UNIT variable added to Regressions 1 or 2 in Table 3, for example, are significant at an α level of .10.

30. Leffler and Rucker analyze in greater detail these advantages, as well as the disadvantages of per unit sales.

choice of efficient sales practices. For example, a seller may be able to benefit from actions that limit the opportunity for buyers to inspect the goods. This possibility lies behind Barzel's (1982) and Kenney and Klein's (1983) intuitive explanations of "pig in a poke" sales techniques like those used by DeBeers. French and McCormick (1984) and Hausch and Li (1993) have argued more generally that actions taken by sellers to increase the cost of information can efficiently limit the dissipation from distributional presale measurement.

Bulow and Klemperer (1996) have recently provided an insightful theoretical analysis of the relative advantages of auctions versus negotiated sales. They find that generally "the value of negotiating skill is small relative to the value of additional competition" (p.180) and, therefore, that a seller will maximize the sale value by auctioning the good. Their model does not, however, account for the impacts of buyer presale measurement costs on the seller's revenue. Negotiation certainly reduces the potential gains to the seller that result from the greater competition on an auction sale. Negotiation also offers the opportunity, however, for the seller and a small number of buyers to bargain over the reduction in dissipation that occurs due to the lower total buyer presale measurement efforts associated with a negotiated sale. An interesting extension of the research in this article is to examine how distributional presale measurement costs interact with the competition effect analyzed by Bulow and Klemperer in determining the profit-maximizing choice between auction and negotiated sales.

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